DEPARTMENT OF COMMERCE
BUREAU OF FISHERIES
HUGH M. SMITH, Commissioner

ARTIFICIAL PROPAGATION OF THE SALMONS OF THE PACIFIC COAST

REVISED AND ENLARGED BY
HENRY O'MALLEY
Field Assistant, U. S. Bureau of Fisheries
In charge of operations on the Pacific coast

APPENDIX II TO THE REPORT OF THE U. S. COMMISSIONER OF FISHERIES FOR 1919

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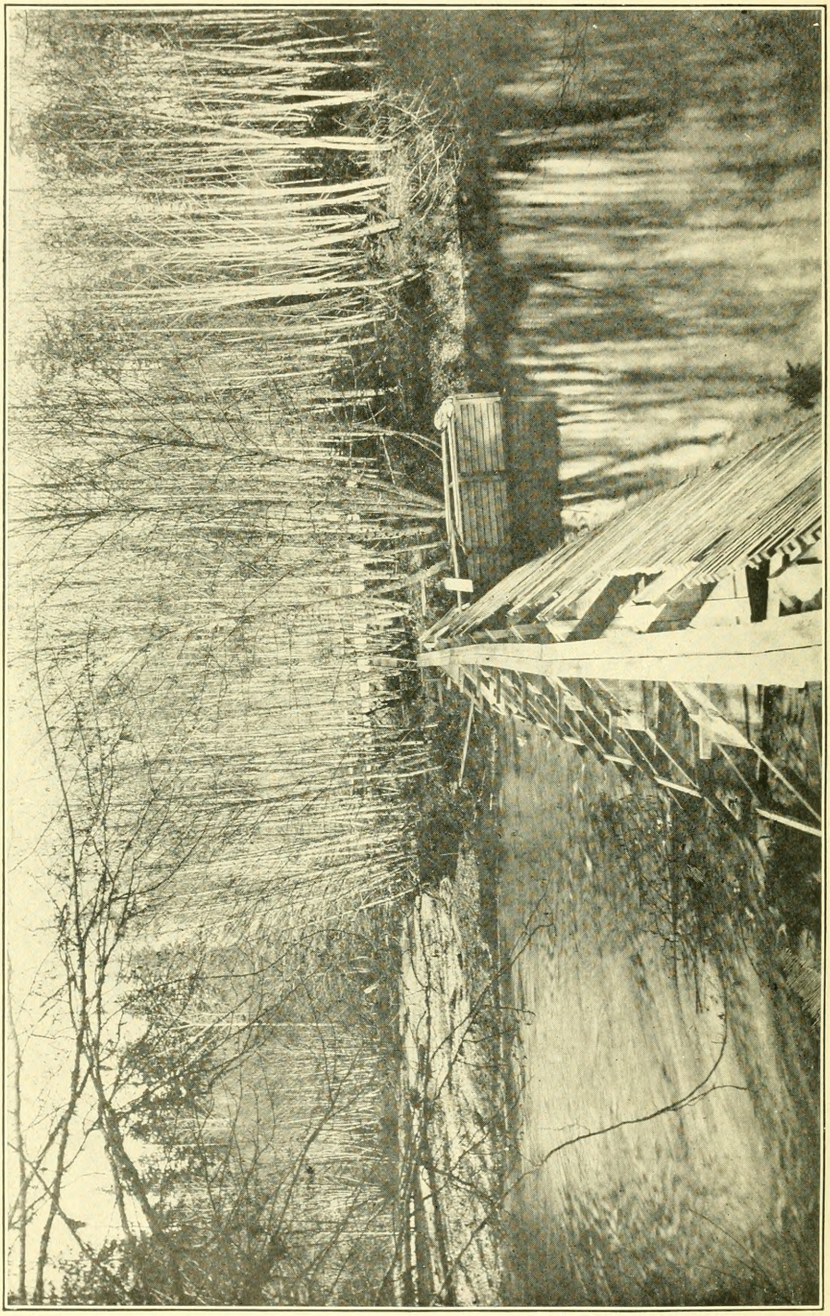


RACK WITH UPSTREAM TRAP, DUCKABUSH RIVER, WASH.

ARTIFICIAL PROPAGATION OF THE SALMONS OF THE PACIFIC COAST.[a]

Revised and enlarged by Henry O'Malley, *Field Assistant, U. S. Bureau of Fisheries, in Charge of Operations on the Pacific Coast.*

THE SALMONS OF THE PACIFIC COAST.

There are five species of salmon on the Pacific coast belonging to the genus Oncorhynchus, namely, the chinook, spring, king, or quinnat salmon (*Oncorhynchus tschawytscha*); the blueback, sockeye, or redfish (*Oncorhynchus nerka*); the humpback or pink salmon (*Oncorhynchus gorbuscha*); the silver or coho salmon (*Oncorhynchus kisutch*); and the chum or dog salmon (*Oncorhynchus keta*). Among the features which distinguish the Pacific salmons from the Atlantic salmon are the larger number of rays in the anal fin and the invariable habit of spawning but once and then dying; the Atlantic salmon may spawn several times.

The characters noted in the following key will usually be sufficient to distinguish the different species of Pacific salmon:

Chinook salmon.—Scales in longitudinal series, about 135; pyloric cœca, 110 to 200, averaging 150; gillrakers comparatively short, from 20 to 25 in number, 9 being above the angle; rays in anal fin from 14 to 19, average 16; branchiostegals, 14 to 19, average 16. Body robust; head conic; caudal fin lunate. Color above dusky, sometimes with bluish or greenish tinge; sides and belly silvery; head dark, with metallic luster, back and sides with prominent spots, usually X-shaped.

Blueback salmon.—Scales in longitudinal series, about 130; pyloric cœca, 75 to 100; gillrakers comparatively long and slender, from 30 to 40 in number; rays in anal fin, 14 to 18; branchiostegals. 13 to 15. Body rather slender; caudal fin lunate; anal and dorsal fins low. Color, sides silvery, no spots on back, which is frequently bright blue.

Humpback salmon.—Scales very small, 200 or more in longitudinal series; pyloric cœca very slender, about 180 in number; gillrakers short, from 20 to 25; anal rays, 15; branchiostegals, 11 to 12. Color, bluish above, silvery on sides; lower part of back, adipose fin, and tail with numerous black spots, largest and of oblong form on tail.

Silver salmon.—Scales large, about 130 in longitudinal series; pyloric cœca comparatively few and large, 40 to 110 in number,

[a] This paper represents a revision and enlargement of the chapter on "The Salmons of the Pacific Coast," from the Manual of Fish-Culture, published in the Report of the U. S. Commission of Fish and Fisheries for 1897, a first revised edition of which was published separately in 1900. The chapter was subsequently issued in separate form under the title "Artificial Propagation of the Salmons of the Pacific Coast."

average 70; gillrakers long and slender, 20 to 25 in number; anal rays, 11 to 15, average 13; branchiostegals, 12 to 14. Body long; head short, conic; snout blunt; eye small; fins small, caudal deeply lunate. Color, bluish green, sides silvery, finely punctulated, as in the chinook, but not so conspicuous.

Chum salmon.—Scales of medium size, about 150 in lateral line; pyloric cœca, 140 to 185; gillrakers from 20 to 25; 13 or 14 rays in anal fin; branchiostegals, 13 or 14. Form of chinook, but head longer and more depressed. Dusky above and on head; paler on sides; very fine spots on back and sides, often wanting; tail deeply lunate, plain dusky or finely spotted, with black edge; other fins blackish.

These salmons are the most important group of fishes entering the rivers of North America. The steelhead (*Salmo gairdneri*), popularly regarded as a salmon, also inhabits the waters of the Pacific coast and adds to the importance of the salmon tribe.

In recent years the annual catch of salmon in the Pacific Coast States, British Columbia, and Alaska has been approximately 585,000,000 pounds, with a value, as placed on the market, of nearly $40,000,000. In 1918 the quantity of salmon canned was 7,829,212 cases of forty-eight 1-pound cans.

CHINOOK SALMON.

The chinook salmon (*Oncorhynchus tschawytscha*) is also known by other names than those given above, as Columbia, Sacramento, and tyee salmon. It is one of the most important of the salmons, being superior in food qualities and attaining a vastly larger size than any of the others. When fresh from the ocean, it is a very handsome, resplendent, well-formed fish. The flesh is of a rich red color in the greater number of individuals, but all runs contain a smaller or larger percentage of fish having white meat. Buyers cut into the shoulder of the fish for arriving at the color. The white meat is equally as good as the red as a food, but the rich red fish have the greater market value, both in the fresh condition and for canning.

No other salmon in the world compares in size with the chinook. In the Yukon River, Alaska, it occasionally attains a weight of over 100 pounds; and in the Columbia River there have been well-authenticated cases of specimens weighing over 80 pounds. Farther south the size is smaller, although in the Sacramento River individuals from 50 to 60 pounds in weight are not rare. In the Columbia 20 pounds is a fair average, and in the Sacramento about 16 pounds.

The known range of the chinook in American waters is practically from Monterey Bay (latitude 36½°) to the Yukon River, but individuals have been seen in Norton Sound, somewhat north of the Yukon, and as far down the coast of California as the Santa Barbara Channel. However, it is not known to spawn naturally in any stream south of the Sacramento River. It extends across Bering Sea to Kamchatka and south to Hokkaido, Japan.

Fish of this species prefer the larger rivers, like the Sacramento, Columbia, Skagit, Nushagak, and Yukon, and they are very persistent in making the ascent. The summer and later runs seek spawning grounds not far from the ocean, but the first or early

spring runs ascend to extreme headwaters. They have been seen crowding up rivulets forming the headwaters of the Sacramento and Columbia Rivers with nearly half their bodies exposed above water. No matter how far the headwaters are from the ocean, some of the run will proceed till forced to yield to an impassable obstruction. On reaching their goal the early fish remain several weeks in deep, quiet holes before going on the spawning grounds. The rate of ascent varies with climatic conditions, the season, and the condition of the rivers, which are affected by melting snow during the spring and summer and by rains in the fall months. They proceed very slowly at low-water stage, sometimes lying for weeks or months in deep pools, and rapidly when the water is at a moderate stage; but at extreme high or flood stage they remain quiet until the water begins to fall and clears, when they resume their journey.

When they first come from the ocean the sexes are very similar in appearance, but as the time for spawning approaches a difference is noted between them, becoming more pronounced as the season advances. The developing ova of the female produces a round, plump form, while the male becomes thin, his head flattening, and his upper jaw curving like a hook over the lower. His eyes sink; large, powerful, white, doglike teeth appear on both jaws; and the fish acquires a gaunt and savage appearance. From the time they reach fresh water their appetites decrease, and their throats and stomachs gradually shrink, until, at the near approach of the spawning season, they have become entirely incapacitated for food, and the desire and the ability to feed has left them entirely. The great reserve of flesh and oils brought with them from the ocean enables them to keep the vital organs active until their mission is accomplished. After reproduction they die on or near the spawning grounds. This singular fact has been disputed, but its truth has been proved conclusively and repeatedly. After they are entirely spawned out they remain on the beds, deteriorating rapidly, the flesh shading off to a light, dirty pink, and they become foul, diseased, and much emaciated. Their scales are partly absorbed and, in the males, wholly enveloped in the skin, which is of a dark-olive or black hue; blotches of fungus appear on their heads and bodies; and in various places there are long, white patches where the skin has been partly worn off. Their tails and fins become badly mutilated, and in a short time the fish die.

They are found feeding in Monterey Bay in any month of the year when food is there. On their way to the spawning beds they reach this body of water about the second week in January and may be caught with hook and line. In February they may be observed in numbers in the Sacramento River. In the Columbia River they appear in March but are not abundant until April or May. They arrive in southern Alaska in May and farther north in June, while it is probably still later before they ascend the Yukon, where the running season is short and may not exceed a month or six weeks. The early runs in the Columbia River are usually from one to three weeks in passing from the mouth of the river to Clifton, a distance of about 20 miles. They first arrive at The Dalles, 200 miles up the river, in the middle of April, and are found in numbers at this point about the middle of June, two months after appearing in larger numbers at the river bay, thus covering a distance of about

100 miles a month. As the season advances the rate of progress up the rivers is more rapid.

The spawning season varies in different rivers and covers a period of at least four months. The spring run begins to spawn at the headwaters of the Willamette and Salmon Rivers, tributaries of the Columbia, in August, while the summer run at the Little White Salmon and Big White Salmon stations, nearer the ocean, begins spawning about September 20. At the Clackamas (Oreg.) station, eggs are secured from the fall run from the last of September to about December 1.

For the deposition of their eggs chinook salmon invariably seek a shallow, gravelly rifle, where the water is a foot or more deep, and the current sufficiently swift to carry and spread the eggs and milt. There is no doubt that in many instances the so-called nest, which is an elongated cavity or depression, often several feet across and 12 or more inches in depth, is started by either the male or female in advance of actual spawning, but as a general thing it is formed by the fish in the act of spawning. At this time both the male and female turn on their sides and by contraction of the abdominal muscles, which produces a quivery motion of the body, effect the simultaneous emission of milt and eggs. At about the same time a forceful movement of the tail and posterior part of the body serves to loosen the gravel and propel the fin forward more or less, thus, by frequent repetition, enlarging the depression and covering the eggs with the loose gravel. It seems evident that this is nature's provision for the protection of the eggs, during the incubation period. With every effort made by the fish in the extrusion of the eggs and milt the depth of the covering is increased, and this serves not only to screen them from the light, which is conducive to the growth of fungus, but also protects them from the prying eyes of trout and other active aquatic enemies.

The length of time consumed in spawning is largely governed by the number of eggs a female contains and also by the temperature of the water. In some instances all of the eggs will be deposited within a day or two, while in others spawning will extend over a period of a week or 10 days.

Both the eggs and the fry are subject to destruction by freshets washing them out of the gravel or covering them so deep that, if they are not actually killed by the pressure on them, it becomes impossible for the fry to work their way out. In many streams spawning occurs during high-water stages in the fall, the eggs in numerous instances being deposited in gravel which is entirely above the water later in the season. Many eggs are lost also by trout lying close in behind the salmon and catching them as they are emitted. Some are rooted out of the nest, and the natural enemies take their toll as the fry emerge from the gravel. It is the instinct of the fry to lie quiescent until the umbilical sacs have been absorbed, when they leave the nest in search of food.

Experiments conducted some years ago by John P. Babcock [a] have demonstrated clearly that only those eggs in natural spawning which are embedded beneath from 5 to 6 inches of sand and gravel produce

[a] Some experiments in the burial of salmon eggs, suggesting a new method of hatching salmon and trout. Transactions, American Fisheries Society for 1910, pp. 393–395, Washington, 1911.

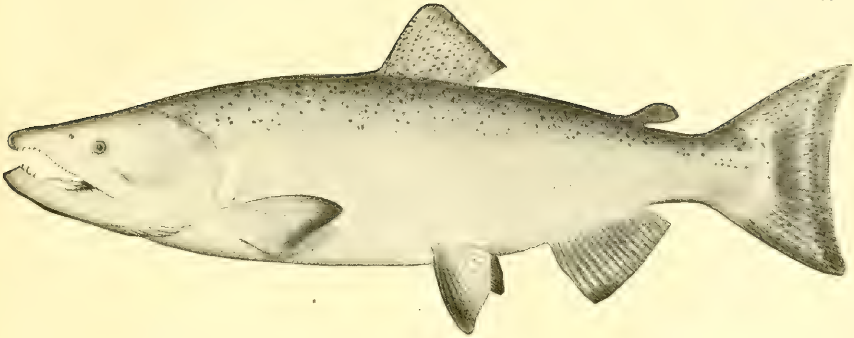


FIG. 1.—CHINOOK SALMON. BREEDING MALE.

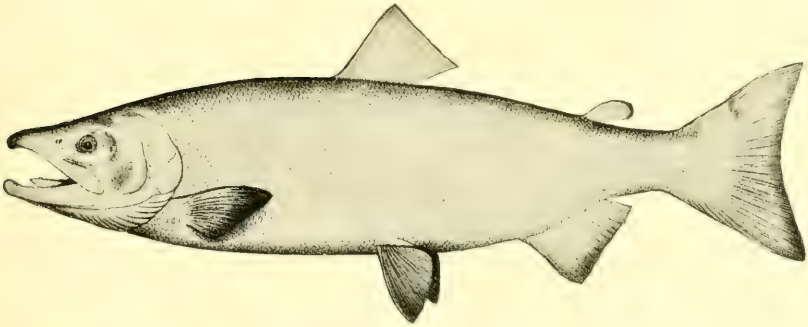


FIG. 2.—BLUEBACK SALMON. ADULT MALE.

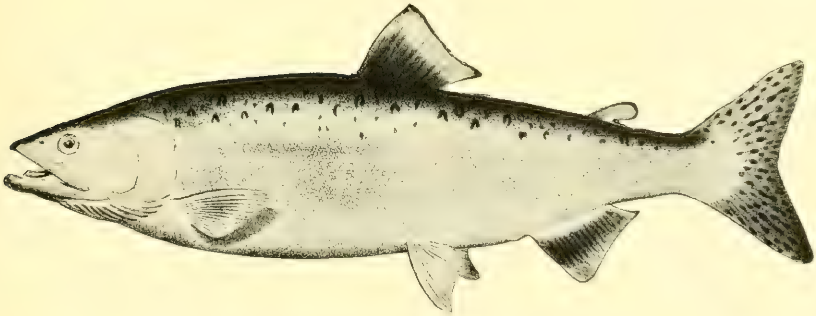


FIG. 3.—HUMPBACK SALMON. ADULT MALE.

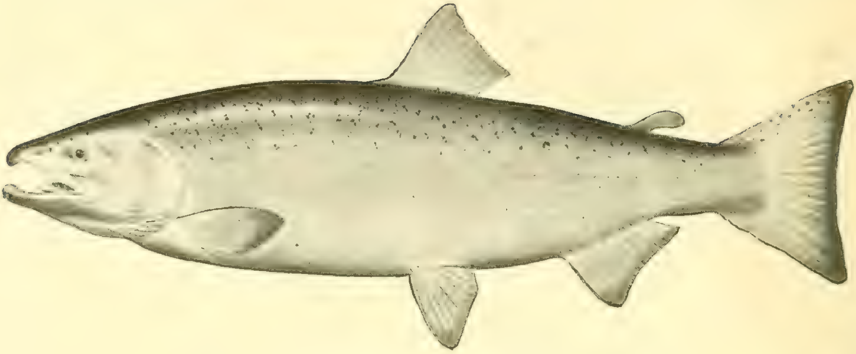


FIG. 1.—SILVER SALMON. BREEDING MALE.

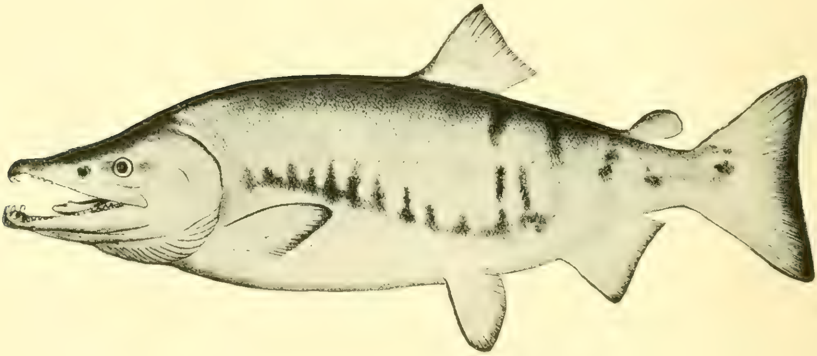


FIG. 2.—CHUM SALMON. BREEDING MALE.

FIG. 3.—STEELHEAD.

alevins that live to attain the fry stage, and that the eggs not so covered are either consumed by active natural enemies or are destroyed by the vegetable mold known as fungus. The experiments have shown that the burial of freshly fertilized eggs of Pacific salmon in sand or gravel to the depth stated does not smother them, but that eggs so treated will hatch, and the resulting alevins will possess the instinct and power to work their way gradually to the surface after the disappearance of the food sacs, at which stage of development they are not attacked by fungus. Eggs buried under from 2 to 3 inches of gravel were found to produce alevins coming to the surface before the sacs had been absorbed, and they were therefore subject to fungus, a very large percentage of them being destroyed in that way, as well as by the more-developed forms of aquatic life. The sacs of fry resulting from eggs buried less than 4 inches deep are so thinly covered when they reach the surface that few, if any, of the fish survive the effects of fungoid growths, and, as such growths are very common in the beds of streams where large numbers of salmon have spawned and died, it follows that very heavy losses of eggs must occur on eggs naturally deposited.

The yield of eggs from the chinook salmon will average from 3,000 to 6,000 per fish. The eggs are of a deep, salmon-red color, measuring about one-fourth of an inch in diameter, and are heavier than water.

In view of the enormous annual catch of this salmon for commercial purposes, the necessity for its propagation became manifest at an early period in the history of the Pacific fisheries. Fortunately, it is readily susceptible of artificial production on a large scale; otherwise the supply in western rivers would by this time have materially fallen off. Since the work began in 1873 on the McCloud River it has grown to larger proportions. It now engages the attention of all the coast State governments, as well as that of the Federal Government, and the work is steadily growing in importance.

As the salmon ascend the rivers they are caught by gill nets, fyke nets, pounds, weirs, seines, wheels, and other devices, but in the Sacramento and Columbia Rivers the greater numbers are caught as they head upstream with gill nets drifting with the current or tide. In the rivers they are comparatively safe from enemies, but immense numbers are destroyed at the mouths of the streams by seals and sea lions.

This species has been introduced into Australia, New Zealand, and Europe, but so far as is known New Zealand is the only country where its acclimatization has been effected. Efforts have been made to establish it in Atlantic streams of the United States, but without permanent results. In some of the fresh-water lakes of New England the chinook salmon has been introduced purely for angling purposes. In such instances permanent fisheries can not be expected save by restocking.

BLUEBACK SALMON.

This species (*Oncorhynchus nerka*) is known in different regions under the names of blueback, redfish, Fraser River salmon, and sockeye. It ranks first of the salmon in commercial value, being es-

pecially important in the Fraser River and in Alaska. The color of the flesh is a rich red, which persists after canning. Large quantities are canned on Puget Sound, in British Columbia, and in Alaska, and its commercial value to that territory is indicated by the fact that during the calendar year 1916 the total pack on the Pacific coast amounted to 2,432,048 cases. Of this total 2,119,442 cases were put up in Alaska, at a valuation of $13,147,994. Comparatively few red salmon are sold fresh in the United States.

It is next to the smallest of the salmons, the maximum weight being 12 pounds, but it seldom attains a weight of over 6 pounds in any instance.[a]

It ranges from Columbia River, Wash., to the far north. In general it ascends only such rivers as rise in glacial and snow-fed lakes. Practically nothing is known of its ocean life. Straggling specimens occur in the Quinault River late in December. It ascends the Columbia River in June and July, and at Kodiak Island it comes in numbers in June. There the heaviest run is in June and July, spawning occurring in August and September. In the Fraser River the largest runs enter during July and August, and in the watershed of this river spawning occurs from late October to the end of December, being at its maximum during November. Quinault and Baker Lakes, together with their tributaries, may be considered typical spawning grounds for this fish in the United States, and in those regions the spawning season extends from early September to late December.

The individuals of this species enter only such streams as have lakes at their headwaters, usually reaching the vicinity of the latter several weeks in advance of spawning time. Many of them deposit their eggs along the lake shores in depths of from 1 to 12 feet of water. Others ascend the creeks or rivers flowing into the lakes and spawn on the riffles in a way similar to that of the chinook salmon. The average number of eggs per fish ranges from 2,500 to 3,000. Except in the breeding season, the color is a clear, bright blue above, with silvery sides and belly. At spawning time the body becomes blood red and the head light green. The male loses his symmetrical form and develops an extravagantly hooked jaw.

HUMPBACK SALMON.

The humpback salmon (*Oncorhynchus gorbuscha*) is the smallest of the Pacific salmons, its average weight being only 5 pounds and its maximum rarely 9. Its range is from Puget Sound northward, probably as far as the Mackenzie River, and it is also common on the Asiatic coast. The southernmost spawning record is in the San Lorenzo River at Santa Cruz, Calif. In Alaska it is the most abundant and generally distributed of the salmons, and in that region there is an annual run of the species. In Puget Sound waters, however, it makes its appearance in numbers only in alternate years. No satisfactory explanation as to the cause of this phenomenon has been

[a] So-called landlocked forms occurring in various lakes weigh only one-half pound when mature. They are commonly referred to as little redfish and have long been regarded as merely dwarfed forms of the anadromous species. At one time they were believed to ascend also from the sea; later it was conclusively proved that they are permanent residents of fresh water, and there is strong evidence that they constitute one or more distinct species.

given. During the fall of 1916, which is known as the off season in Puget Sound, 1,887 cases were packed. This shows a healthful increase over the seasons previous to the Bureau's attempting the establishment of an annual run in this region.

In nutritive value the fresh-run humpback is scarcely inferior to any other salmon. While the flesh has a very fine flavor, it is paler than that of the chinook or blueback salmon, and it loses its color when canned. The total amount of this species canned during the calendar year 1916 was 2,036,077 cases, of which amount 1,753,546 cases, valued at $6,446,168, were packed in Alaska.

The humpback salmon usually seeks the smaller streams for reproduction, depositing its eggs a short distance from the sea, sometimes within a few rods of the ocean. At Kodiak Island, Alaska, where it is often very abundant, it arrives in the latter part of July, the run continuing only a few weeks. Spawning occurs in August. The eggs, of which there are about 2,000 per fish, are smaller than those of the chinook, but larger than those of the blueback and paler than either.

Shortly after its arrival from the ocean, and with the approach of the spawning season, it develops on its back a prominent hump, which, with the distortion of the jaw, gives the fish a very singular appearance. As is the case with the other salmons, it dies on the spawning bed or after being swept to sea by the current.

SILVER SALMON.

The silver salmon (*Oncorhynchus kisutch*) is also known as silversides and coho salmon. It is a beautiful fish, having a graceful form and a bright, silvery skin. Its flesh is usually of a bright-red color; but, as this fades on cooking, it is less highly regarded for canning, though large quantities are thus utilized on the Columbia River, Puget Sound, and the short coastal streams of Oregon and Washington.

In 1916 the total pack was 715,815 cases, of which 265,184 were put up in Alaska. Its range is from Monterey Bay to northern Alaska, and as far south on the Asiatic coast as Japan. It ascends the rivers to spawn in the fall and early winter, when the waters are high. In most of the rivers which it frequents there appear to be two well-defined runs, the early run ascending to the headwaters, while the later run is found in the streams nearer the ocean. The early run is composed of small-sized specimens. In Alaska the average weight of this salmon is nearly 15 pounds, and in the streams farther south about 8 pounds. It rarely attains a weight of 30 pounds. The average egg production per fish is about 3,500.

CHUM SALMON.

The chum salmon (*Oncorhynchus keta*) is the least valuable of the Pacific salmons, although it is canned and dried in large quantities on the Pacific coast and in Alaska. Its average weight is 10 pounds, and the maximum is about 20 pounds. It is found from the Columbia River northward, being especially abundant in Alaska. It is taken occasionally in the Sacramento River. When just from the ocean, the flesh is of a very pale red color. At that time it is a very

good fish, but it deteriorates rapidly in fresh water, and it loses its color in the can. It spawns in shallow riffles and creeks, usually at no great distance from the ocean. Large quantities are packed in Oregon, Washington, and Alaska. The production of canned chum salmon in 1916 amounted to 1,500,332 cases, of which 715,238 cases were put up in Alaska.

STEELHEAD.

Another anadromous fish found in Pacific coast waters is the steelhead (*Salmo gairdneri*), commonly known as steelhead and steelhead trout, and in many instances erroneously classed with the Pacific salmon in the State laws. It resembles in form, size, and somewhat in general appearance the salmon of the Atlantic coast, but is distinguished from the Pacific salmons by its short anal fin of not over 12, and usually 9 or 10, rays, square tail, small head, rounded snout, comparatively slender form, light-colored flesh, and its spring-spawning habit. Its average weight in the Columbia is about 12 pounds, but specimens weighing 42 pounds have been found in the Skagit River.

Its range is very extended, reaching from Santa Barbara on the southern coast of California to the Alaskan Peninsula, and perhaps to the Arctic Ocean. It is found in almost all the streams of the Pacific States which empty into the ocean. The only run of this species of commercial importance in the Columbia River begins in late June and is in full force in July and early August. It reaches Seufert, Oreg., about the close of the blueback run, and some of the fishing wheels catch practically nothing else. This fish feeds while in fresh water, and does not always die after spawning, but it deteriorates from the time it enters fresh water until the following spring, and spawns between the months of February and May. Its movements in other rivers on the coast are not materially different, except that it enters the southern rivers earlier and the northern rivers later than it enters the Columbia. Like the chinook salmon, the steelhead ascends for long distances, and it has been found as far up tributaries of the Columbia as the ascent of fish is possible. The number of eggs per fish ranges from 6,000 to 8,000. The greater quantities of steelhead trout are caught during the winter and spring months and are utilized in a fresh state, large quantities being shipped to eastern markets in refrigerator cars. However, during the calendar year of 1916 cases of this species to the number of 24,999 were packed.

ARTIFICIAL PROPAGATION.

Artificial propagation having been first applied on the Pacific coast to the chinook salmon, the description of methods which follow is based mainly upon the practices employed with that species. In 1916 the number of salmon and steelhead eggs collected by the Bureau of Fisheries, expressed in millions, was as follows: Chinook, 108; blueback, 105; humpback, 32; silver, 13; chum, 29; steelhead, 14. These were collected at the Afognak and Yes Bay stations in Alaska; at stations located on tributaries of Puget Sound and in the Quinault Indian Reservation, Wash.; at Clackamas and its auxiliaries in the Columbia River Basin and in southern Oregon; and

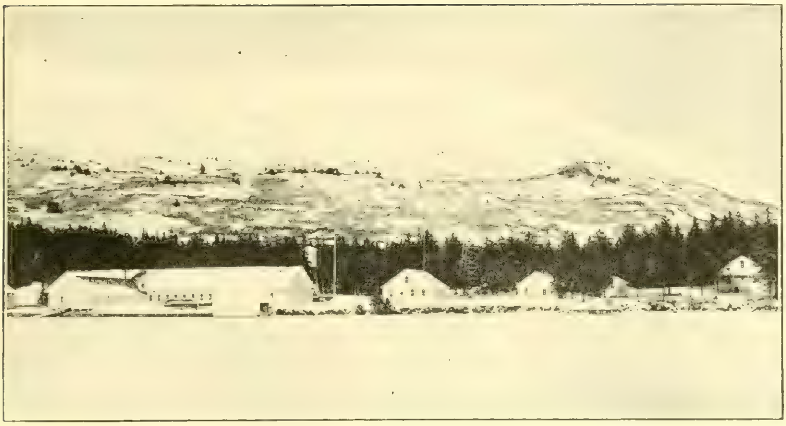


FIG. 1.—SALMON HATCHERY, AFOGNAK, ALASKA.

FIG. 2.—SALMON HATCHERY AND REARING PONDS, YES BAY, ALASKA.

FIG. 1.—ROGUE RIVER (OREG.) HATCHERY.

FIG. 2.—CLACKAMAS (OREG.) HATCHERY.

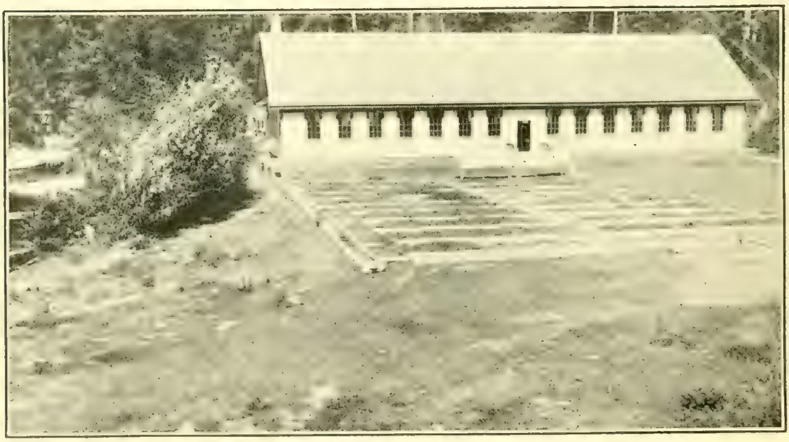


FIG. 3.—BIRDSVIEW (WASH.) HATCHERY.

at the California stations on tributaries of the Sacramento and Klamath Rivers. In addition, the private hatcheries operated by the salmon-cannery interests of Alaska, known as Fortmann, Karluk, Quadra, Hetta, and Klawak, which have been hatching blueback salmon for years, collected in 1916 over 87,000,000 eggs. The normal capacity of these five establishments is 197,000,000 eggs per annum. The Bureau's two hatcheries in Alaska have each a capacity of 72,000,000 eggs.

CONSTRUCTION OF RACKS.

The eggs found in salmon that are captured for commercial purposes are in a green state, and, therefore, in all hatchery operations of importance it has been found necessary to provide for the egg supply by installing requisite devices for the capture and retention

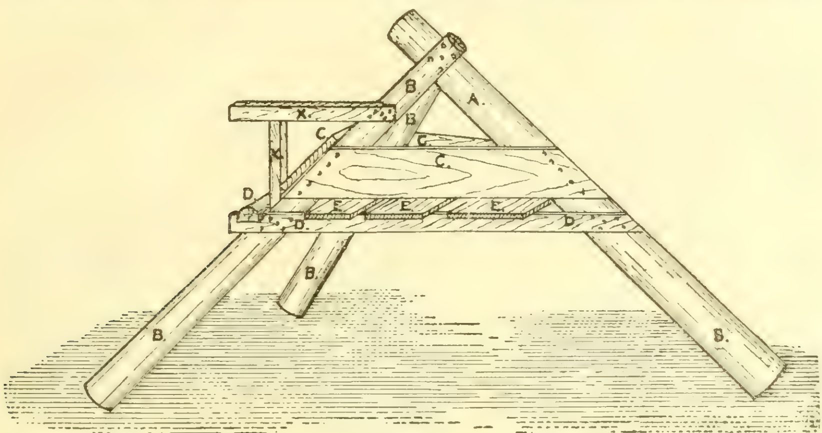


FIG. 1.—Three-legged rack horse or trestle: *A.*, horse head; *B.B.*, horse legs; *C.C.C.*, 12-inch boards to make sides of crib and also to act as braces; *D.D.D.*, leg braces which also support bottom of crib; *E.E.E.*, bottom of crib; *X.X.*, bracket for supporting walk.

of the brood fish. Such fishing is conducted at or near the spawning grounds.

The site selected for the placing of the racks should be in a good spawning locality. The upper rack is placed at the head of a riffle, and the stop or lower rack is installed just below a deep pool, the distance between the two depending upon topographical conditions. There is thus provided between the upper and lower racks a proper spawning and fishing area, with a deep pool for a resting place for the immature fish. In this inclosure the fish are held until removed for stripping. The racks are designed to control the movements of the fish regardless of the water stages, as failure to do so means the loss of a season's take of eggs.

The usual form of rack constructed in the rivers of Washington and Oregon and in most of the streams in California is built on trestles or three-legged horses, their sizes depending upon the character of the streams to be closed, and their length upon the depth of water and the angle or slope to be given the rack. The legs are made of pile timber from 8 to 12 inches in diameter. The upper leg

is longer than the other two, which are of equal dimensions, and is attached to them at an angle of 90°, the spread between the others being about 60°. The legs are braced and held in place by poles about 4 inches in diameter, which are spiked to the sides midway from the ground to where the legs are joined, and, as an extra precaution, an additional brace is nailed across the two rear legs.

The braces strengthen the bottom of the crib, which is made of 1-inch rough lumber, and the 12-inch boards composing its sides serve as an additional brace to the legs. Such a crib will hold from 100 pounds to almost a ton of rock, the amount varying with the size of the braces used and the current which it is expected to withstand.

The trestles are set from 8 to 12 feet apart directly across the stream on the site selected for the rack, the distance between each being governed by the size of the stream and the strength of rack desired. The trestles are then lined up and loaded with stones, and two stringers from 8 to 12 inches in diameter are put on and spiked to the upstream side of the forward leg. While the position of the stringers must be governed to some extent by the height of the rack, it is usual where the rack is of ordinary construction to place the upper stringer about 30 inches above the water surface and the lower one midway between that point and the river bottom. On large streams a third stringer is sometimes used to good advantage.

Where the bed of the stream is of hard formation 2 by 3 fir pickets are put down even with the bottom at intervals of 1½ inches and nailed to the stringers, the 2-inch surface being placed to the current and the upstream edge beveled in order to present the least possible resistance to the current. In streams with soft shifting bottoms it is often necessary to drive the pickets. As a further precaution against the escape of the salmon by the loosening and displacement of the pickets by the current, or by the struggling of the fish, a block 3 inches long by 1½ inches wide is nailed to each picket at a point halfway between the lower stringer and the bottom. A layer of bowlders and rock from 3 to 5 inches in diameter is then placed in front of the rack at the point of the pickets to close effectually all openings between the ends of the pickets and the river bottom; and brackets for supporting a walk are nailed to the downstream side of the trestles, thus providing a means of keeping the rack cleared of débris at all times.

In streams where shingle bolts, cordwood, and driftwood occur, a gate is provided for their passage, and the necessary sheer booms are constructed in front of the racks to guide the timbers to the opening. The gate should be built between two trestles which have been placed 8 feet apart, and the open space connected by a stringer placed below the surface of the water at a depth of at least 18 inches. Pickets are attached to this stringer in the usual manner, except that they must be sawed off even with its top, and the sides of the space are squared up and walled with 1-inch lumber.

The gate is constructed of 1 by 4 inch strips 12 or more feet long, which are placed on edge at intervals of 1½ inches, well blocked and braced. It is then hinged to the stringers in such a manner that it will swing freely. One way to accomplish this is to bore holes through the ends of the strips and insert 1-inch pipe, the ends of which, projecting a few inches on either side of the gate, allow it to

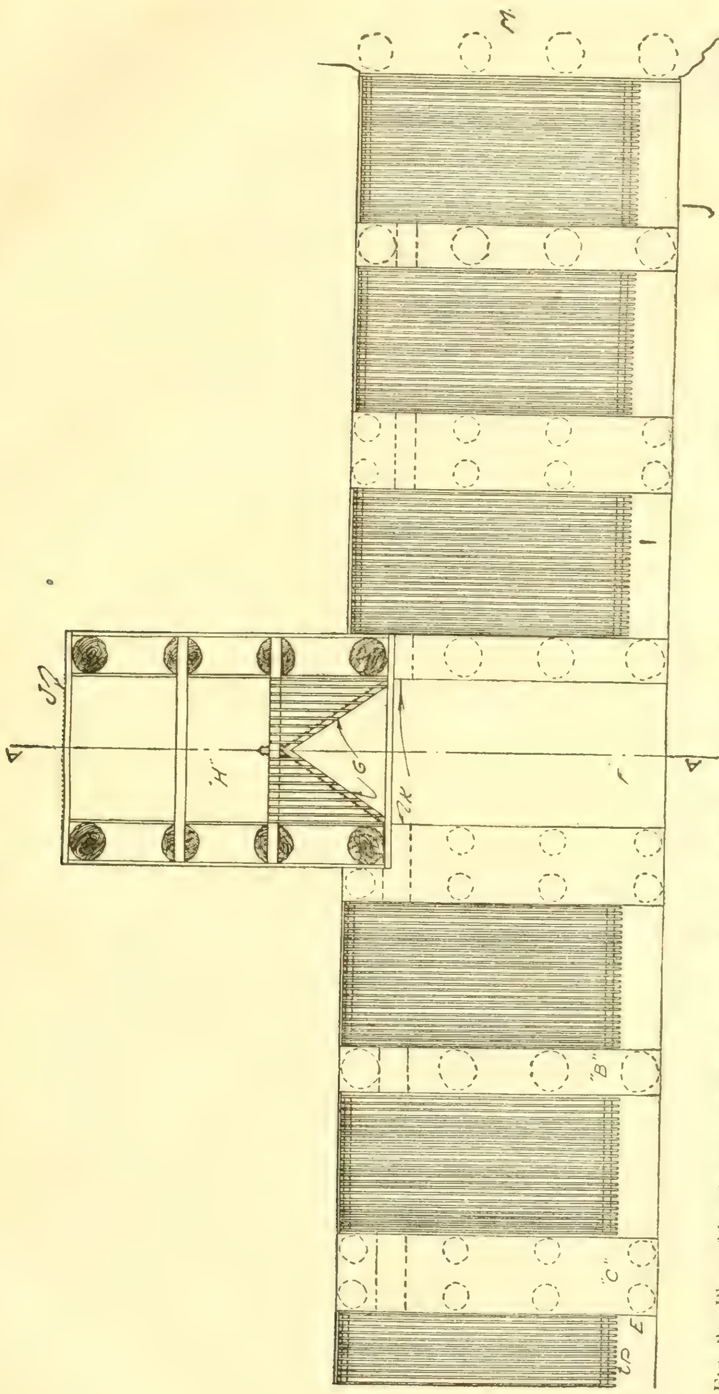


FIG. 2.—Plan of barricade in Phinney Creek, near Birdsview, Wash.: *B* and *C*, single and double rows of piles, respectively; *D*, downstream end of racks; *E*, floor under racks; *F*, open channel to trap; *G*, walls of V-shaped approach to trap; *H*, trap; *J*, screen at head of trap; *K*, openings in pier for passage of fish to *G*; *L* (fig. 3), door in north side of V-shaped approach; *M*, abutments.

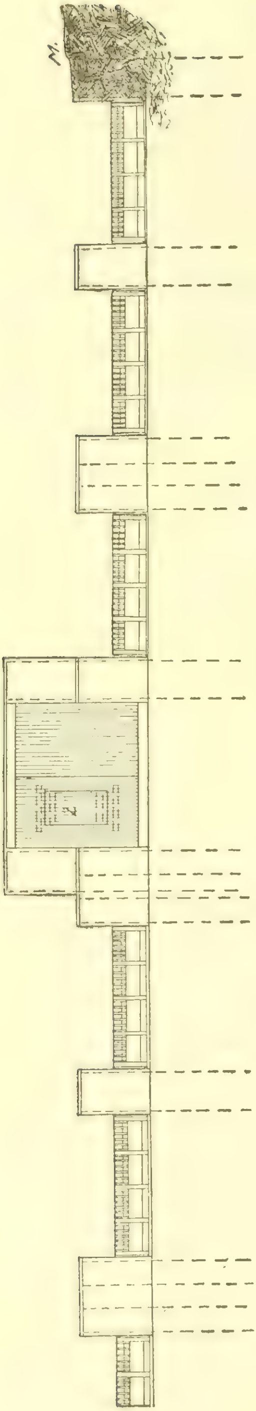


Fig. 3.—Front elevation of barricade shown in figure 2.

turn in eyebolts in the side walls. To prevent the fish passing through when the gate is open, a 12-inch board should be nailed across its under side at such an angle that the current rushing against it will lift the lower end of the gate just above the surface of the water. Floating objects coming down the stream are carried onto the gate, which sinks from their weight, and as the current carries the object on the gate closes automatically.

Racks constructed in accordance with this method will often stand submerging several times in the course of a spawning season, and at its close remain practically undamaged.

A barrier that has stood the test of several years and has proved that it will operate successfully in almost any stage of water is described in the following paragraphs.[a] The design is to be credited to A. H. Dinsmore, former superintendent of the Baker Lake (Wash.) station.

A permanent barrier at the Birdsview station, an auxiliary of the Baker Lake station in Washington, is of novel construction and calls for more than passing notice. This barrier is located in a portion of Phinney Creek, where formerly there was a dam built for the purpose of obstructing the passage of steelhead trout. When the dam washed out, a new channel formed and the river bed was very much broadened.

The first step in the construction of the new barrier was the laying of four heavy log stringers across this new channel from the abutment on the north to the new bank on the south side of the stream. The logs were let down through the dam foundation to low-water level on the north side, and the deep channel under them on the south side was filled with brush and gravel. The logs were spotted down to form a practically level bed, reaching the width of the stream. Heavy piles were then driven behind each stringer to form alternate single and double rows extending up and down stream. The log stringers were next planked over, forming a platform 18 feet wide, similar to a regular dam apron, extending from the north abutment to the final row of piles on the south side, a distance of about 140 feet.

By planking the sides of the single row of piles and all around the double rows and filling the space with rocks, piers 4 feet high and approximately 2 feet and 4 feet wide were formed. Through each pier at the bottom, behind the upstream pile, openings 1 foot square were left,

[a] Titcomb, John W.: Fish-cultural practices in the Bureau of Fisheries. Bulletin, U. S. Bureau of Fisheries, Vol. XXVIII, for 1908, part 2, pp. 728–732. Washington, 1910.

connecting the spaces between the piers. These spaces, 12 in number, are approximately 8 feet wide and are filled by swinging gates hinged to a 3 by 12 inch timber, spiked securely to the piers on either side and forming a dam or flashboard across the space above. By the insertion of other flashboards above this one a tight dam 4 feet high can be quickly formed at any time. The utility of this feature will be explained elsewhere.

The gates are made of 1 by 4 inch fir set on edge and nailed to 2 by 4 inch joists, being strengthened by 2-inch blocks set between the rack bars and nailed to them and the joists. These blocks thus determine the width of the interstices in the gates. At the upper end of each gate an auger hole is bored through the bars and blocks, to accommodate a 2-inch iron pipe, which passes through the entire upper end of the gates. Ringbolts clasp these pipes and are fastened to the 3 by 12 inch timber forming the flashboard, acting as hinges upon which the gates swing. At the lower end of each gate a wide board, $1\frac{1}{4}$ by 16 inches, is secured by means of braces, forming an angle of 45° with the lower end of the gate.

At an ordinary stage of the stream the downstream ends of the gates rest on supports which hold them a foot or more higher than the upper ends, the water passing down through them to the floor of the apron, where it runs away. The fish working up under the gates to the dam board find the cross passages through the front end of the piers and finally reach the trap. It was expected that during freshets the current acting on the flashboard would always keep the lower ends of the gates above the surface of the water, and up to a certain

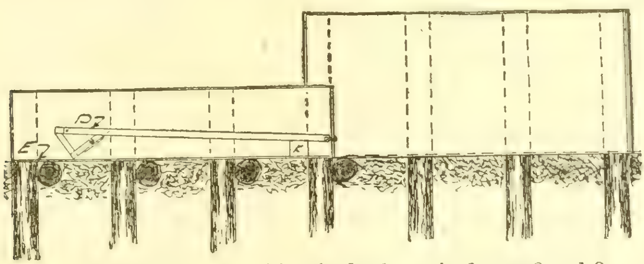


Fig. 4.—Side elevation of barricade shown in figures 2 and 3.

point this expectation was realized, but at very high stages of the stream the large quantity of gravel in the water soon clogs and sinks the gates. As the gates are only two-thirds the length of the apron, however, and rise toward the lower end, the water shoots over them with such force that it is projected some distance below the end of the apron, and fish attempting to scale the obstruction fall far short of the ends of the gates. The barrier has been watched many times when fish were jumping and when the largest drift ran clear, and none has ever been seen to pass it.

By means of the dam boards entire control of the current can be had during ordinary stages of water and any desired quantity sent to any section of the barrier. Thus a strong current can be maintained through the trap section, leading the fish to it, and when it is desired to remove the fish from the trap the water can practically all be turned to some other section of the barrier.

One of the greatest difficulties in maintaining traps in the streams in this section is due to the tremendous quantities of gravel carried in the water during freshets, a sufficient amount being frequently deposited in front of a trap at such times to change the course of the stream. With the present form of barrier no trouble is experienced from this source, the insertion of the dam boards and the opening of one space at a time quickly clearing away the accumulated gravel.

The ninth and tenth piers were continued upstream by driving three additional piles above each. The piers form the sides of the trap. Its floor is a plank bottom, similar in construction to the apron, and the front is barred by $1\frac{3}{4}$-inch pickets placed $1\frac{3}{4}$ inches apart, the fish entering by the usual upstream V of pickets. To protect the trap from high water the two piers between which it is located were carried to a height of 8 feet. When it is desired to fish the trap, the gate at its head is closed and entrance is made from below by means of a door in the north side of the V.

The upper end of the fishway of the old dam was left in place, the narrow passage between it and the new trap protecting the spaces at the south end of the barrier from the current and from drift. These spaces have been racked above and below to form commodious pens for males and unripe females. The south end of the barrier is protected by a substantial abutment.

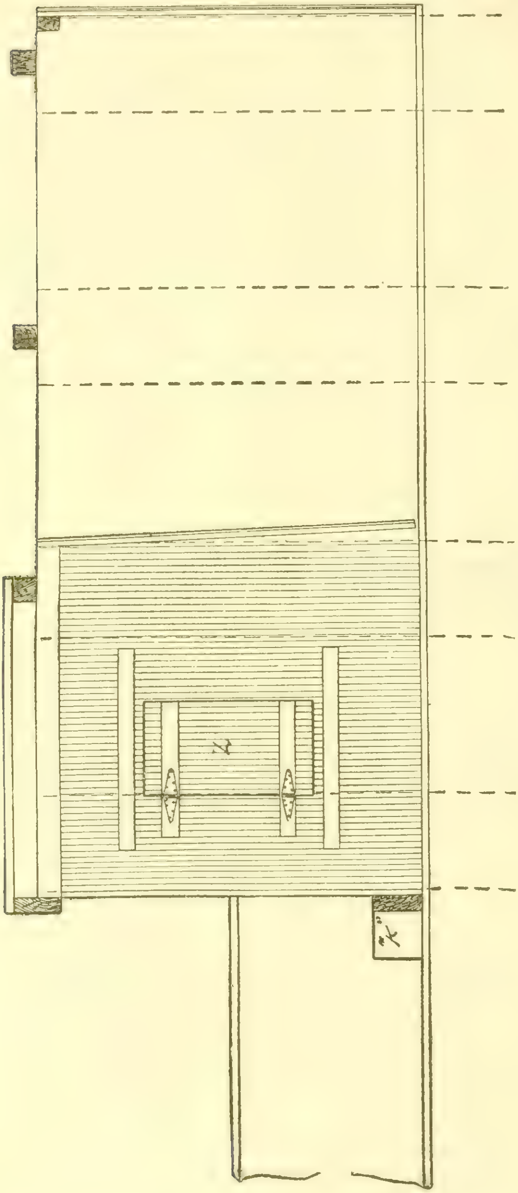


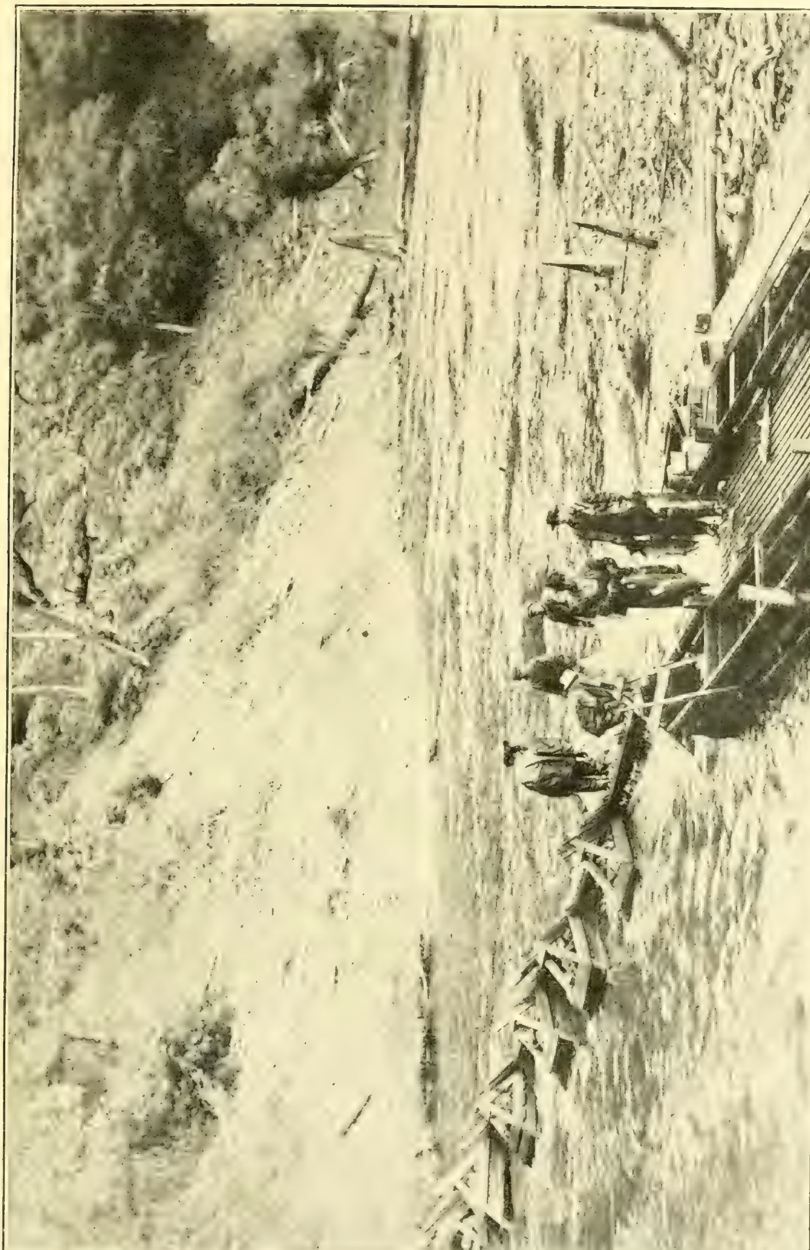
Fig. 5.—Section on line A—A of figure 2.

The maintenance of the racks in Phinney Creek has been a very heavy item of expense in past years, and the trap was frequently carried away by freshets just at the height of the season, allowing large numbers of fish to escape and considerably reducing the season's take of eggs.

Concrete piers have been used in some of the California rivers, but they are now considered too expensive for fish-cultural work on an economical scale. In some of the streams in that State piles are substituted for trestles. These are sawed at the proper angle, capped with timbers of the right size, and used for supporting the rack stringers. In constructing racks in this way the pickets are usually placed in sections and hoisted into position by means of a derrick. Mudsills are embedded in the gravel beneath the rack and a floor placed thereon.

OBTAINING SALMON FOR PROPAGATION.

The manner of capturing the brood fish varies in accordance with the nature of the stream where the work is conducted. On some rivers the upstream trap is successfully used in connection with the head rack (Pl. 1). The tray used is sometimes a square or oblong inclosure; at other times it is a pen constructed of lumber. In either case the entrance is made on the principle of



DOWNSTREAM TRAP, LITTLE WHITE SALMON RIVER, WASH.

the ordinary pound net. In their eager efforts to pass upstream the fish go through the V-shaped mouth of the trap, and, having once entered, they seldom find their way out. The trap is usually covered to prevent the escape of the fish by jumping.

In streams where the current is strong, as in Oregon and Washington, the fish are sometimes taken on the riffles by means of gill nets; but, as many are killed or injured when so caught, this method should be employed only as a last resort.

In the comparatively slow streams of California it is customary to employ drag or sweep seines of suitable length and depth, which are operated below the head rack and above the retaining rack.

Where the natural conditions will permit, the most economical means of capturing salmon is by the use of a downstream trap. The use of this device necessitates that the upper rack be placed across the river at the head of a spawning riffle having a good fall. The wings of the trap, constructed on the same principle as the rack and with openings provided near the shore ends for the entrance of the salmon to the spawning waters below the main rack, are run downstream from one or both shores, as local conditions may require, and at their convergence the trap is located. The trap, which is usually about 5 feet wide, is made of smoothly dressed slats or poles, the small ends of which are nailed to a light sill sunk in the bed of the stream, with a space of $1\frac{1}{2}$ inches between each pole, to allow the water to flow through freely. From the sill they rise in a gentle incline downstream to a level a few inches above the point where the water runs through, and they are then sprung down and nailed to sills, forming the bottom of the trap. The sides of the entrance and the trap proper are usually made of poles or pickets placed horizontally, with sufficient space between to permit water to escape freely. The sides of the entrance are well braced to withstand the pounding of the salmon when rushing into the trap in numbers, and on either side of the trap live pens for holding the ripe fish are constructed. Across its entrance a grating is placed to prevent the fish from being carried into it when not in use.

When the trap is to be fished, the openings in the lead are closed and the grating at the entrance removed. The seine is laid out at the head of the riffle, whence it is rapidly carried by the current downstream toward the trap. The fish on the riffle become frightened at the seine and run downstream. Following the converging leads and traveling rapidly with the current, they are driven into the mouth of the trap. Before they can turn, their momentum carries them high and dry onto the trap floor, where an attendant picks them up, liberates the green fish in the water below, and places the ripe males and females in their respective pens. The fish which try to turn back before reaching the trap are caught by the heavy leaded seine and held against the lead racks until the fishermen find them.

At the Big White Salmon station of the Bureau of Fisheries success has been attained by purchasing salmon from the fish-trap men and towing them in live cars to an inclosure made by racking a spring creek having a soft, sandy bottom, which is particularly adapted to the successful ripening of immature fish. The death rate of the fish while being held there to ripen is small, and the eggs taken from them are of excellent quality.

At Baker Lake the fish are taken in a web trap as they enter the lake and are impounded in a slough at the head of the lake and held there successfully for several months. When mature, they are removed from the inclosure by means of a drag seine.

Where immature salmon are to be held for any length of time, an inclosure with a soft, muddy bottom should be provided for the purpose, it having been found by experience to be far superior to a gravel bottom.

A rather novel method is employed for capturing silver salmon and steelheads where the barrier preventing the ascent of the fish chances to be a dam or a natural fall. At an advantageous point, where the water pours over the crest of the barrier and where the fish are known to jump in their attempt to ascend the river, a device known as a jumping box is installed, being placed back of the fall at a sufficient height, so that when the fish jump they will be likely to fall through the water into it. The length of this box or trough is governed by local conditions; its width varies from 18 to 24 inches, and it is given a fall of at least 12 inches to each 10 feet of length. A covered flume with a sharp fall connects it with a live box, which is placed in the stream in such a manner as to insure its protection so far as possible from high water, and at the outlet of the flume leading to the live pen a downstream V is placed. This, together with a secure cover, serves to prevent the escape of the fish from the pen.

In the operation of this contrivance the fish fall into the jumping box, and before they can regain their equilibrium they are carried into the live pen and are held there until removed. Care must be taken to prevent overcrowding in the pen, as, when the fish are jumping from 6 to 9 a. m. and from 3 in the afternoon until sundown, they are apt to be taken in such numbers that loss from smothering will result, unless the pen is emptied at frequent intervals.

TAKING AND IMPREGNATING THE EGGS.

When chinook-salmon eggs are taken on a large scale, say from a half million to three or four millions per day, as is customary at the Little White Salmon station on the Columbia River, spawning usually occurs daily throughout the egg-collecting season, it being impracticable to hold the fish in pens for any length of time, as they injure themselves more or less in fighting against confinement, and many eggs are dropped.

The females are placed in pens by experienced men, and ripe ones only are put in. Of the signs that indicate ripeness in a female salmon the separation of the eggs in the ovaries is the surest. Specific signs are all fallible, however, and the spawn taker must rely mainly on an indescribable ripe look, which is neither color, shape, nor condition of organs, but a general appearance which shows at a glance that the fish is ripe. This knowledge can be gained only by experience.

An attendant gets into the pen containing the females and catches a fish by the tail with his left hand, on which is worn a woolen glove or mitten as an aid in maintaining his hold. He kills the fish by a blow on the head with a club and, casting it on the trap floor, repeats the operation until from 40 to 50 have been killed. At some stations it is customary to cut off the tails at the base of the caudal

STRIPPING FEMALE CHINOOK SALMON, LITTLE WHITE SALMON (WASH.) STATION.

FERTILIZING EGGS OF CHINOOK SALMON, BIG WHITE SALMON (WASH.) STATION.

with a broadax, so that the fish may bleed freely. While this is not absolutely essential, it prevents the eggs from coming in contact with a large quantity of blood. The fish are washed by dashing water over them, the blood escaping through the open floor.

Male fish are then thrown out from their pen and left long enough to undergo the exhaustion necessary to permit their being handled without much difficulty.

The spawn taker uses a "straight-jacket," as it is called, merely for the convenience of holding the fish. This is a sort of trough made the average length of a salmon and hollowed out to fit its general shape. A female is picked up by the gills and placed in this device. With a sharp, short-bladed knife the spawn taker makes an incision from the vent through the thin abdominal wall along the side, and the eggs flow out into a spawning pan or bucket held by another attendant. This is immediately passed to a third man, while a fourth man picks up a male fish. Grasping the tail of the fish with his left hand, and thrusting its head under his right arm, or in the case of a larger fish, between the knees, with his right hand he presses the milt out upon the eggs as soon as possible after they are taken. The eggs and milt are then thoroughly mixed by stirring with the hand. After being allowed to stand for a few minutes the milt is washed off, and the eggs are transferred to buckets and carried to the hatchery. Here they remain undisturbed until they have become water hardened and separate, when they are measured into egg baskets. The male fish is returned to the stream for use in future spawning operations.

Blueback salmon in Alaska begin to leave the lakes in late August and September and ascend the streams to their headwaters to spawn. At suitable places near the mouths of such streams the fish are intercepted by racks, and seining operations are conducted in the waters below. The seine used, which is about 300 feet long, is loaded on a boat at a point below the rack, and, one end being held on shore, the remainder is distributed to posts projecting from the rack to the farther side of the stream. From here the boat continues downstream in a long sweep until the seine is played out to form a semicircle. The end last played out is operated by a man in waders, while the boat with the lead rope continues on to the starting point on the shore. At a given signal men stationed along the rack release the seine and follow it as it is hauled toward the shore, the two ends being brought together so as to completely envelop the fish, which are gradually worked toward the center. The seine is then stretched or hung on horses or tripods, and men equipped with woolen gloves grasp the corralled fish by the tail, segregate the sexes, and distribute them in boxes conveniently placed for the purpose. These boxes, supported on legs about 3 feet long, are made of three-fourths-inch lumber and divided by partitions into from 8 to 10 cells, each of them large enough to hold a fish placed in it head foremost, leaving about 6 inches of the tail protruding.

An operator stands at a box in which females have been placed and assorts them to determine as to their spawning condition, placing the ripe ones in another box and throwing the unripe ones back into the stream. A second man stands at the box containing the ripe fish and removes them one by one, killing them by a blow on the head with a club. They are then placed on a spawning table having a top 2 by

10 feet in dimensions, 6-inch sides, and legs about 3 feet long, with a slope toward the operator at the other end. Across the table, for convenience in taking the eggs, is placed a small platform or bridge 1 foot in width, with a slope of about 30° toward the upper end of the table, the face of which is studded with sharp-pointed nails one-half inch long to hold the fish in place.

The spawn taker removes a fish from the table and places it on the platform with the head toward him, his left hand resting near the middle of its back. With his right hand he rips open the abdomen from a point between the pectoral fins to the egg vent by means of a sharp-bladed knife, having a guard which permits the blade to project three-fourths of an inch. If the eggs are ripe they are easily removed by slightly inclining the fish toward the lower side of the board, where they gently fall into a pan placed to receive them. The dead fish is then thrown aside and the operation repeated. After two females have been spawned a man at the opposite side of the table removes the pan, replaces it with an empty one, which has first been moistened with water, and passes the pan of eggs to the operator handling the male fish, to be fertilized. After fertilization has been accomplished, the eggs are turned into a washing box and held in a quiet current in the stream to clean up. This box somewhat resembles a corn popper in its construction, being made of fine-meshed wire and provided with a long handle and a hinged cover, with a clasp to hold it in position. In its bottom is a small trapdoor, operated by a lever near the end of the handle. After remaining in the stream a few minutes the eggs are emptied through the trapdoor into a bucket submerged about a foot under the surface of the water. Here they are held for half an hour to harden and are then carried to the hatchery, measured, and distributed in standard salmon-hatching baskets, 50,000 being placed to a basket.

HATCHING APPARATUS AND METHODS.

The hatching apparatus usually employed is the so-called standard salmon trough, with wire-cloth baskets. The troughs, which are generally constructed of cedar and redwood from 1½ to 2 inches, dressed, are 16 feet long, outside measure, and 14 by 6½ inches, inside measure. They are arranged in pairs, two or three pairs being placed end to end on different levels, with a fall of about 6 inches between each pair.

Metal partitions divide each trough into compartments just enough longer than the baskets to permit of their being raised and lowered and subjected to slight tilting. The essential feature of this trough is the perfection of water circulation attained by means of cross partitions or riffle dams inserted at either end of each compartment. These partitions are made of No. 20 galvanized sheet iron and are held in place by saw scarfs in the sides and bottom of the trough.

The first riffle dam is placed 7½ inches from the head end of the trough, reaches entirely across, and extends from the bottom to within about 1½ inches of the top. Two inches below this point a similar dam extends across the trough, reaching from the top to within 1½ inches of the bottom. Twenty-six inches farther down similar dams are arranged, and so on throughout the entire length of

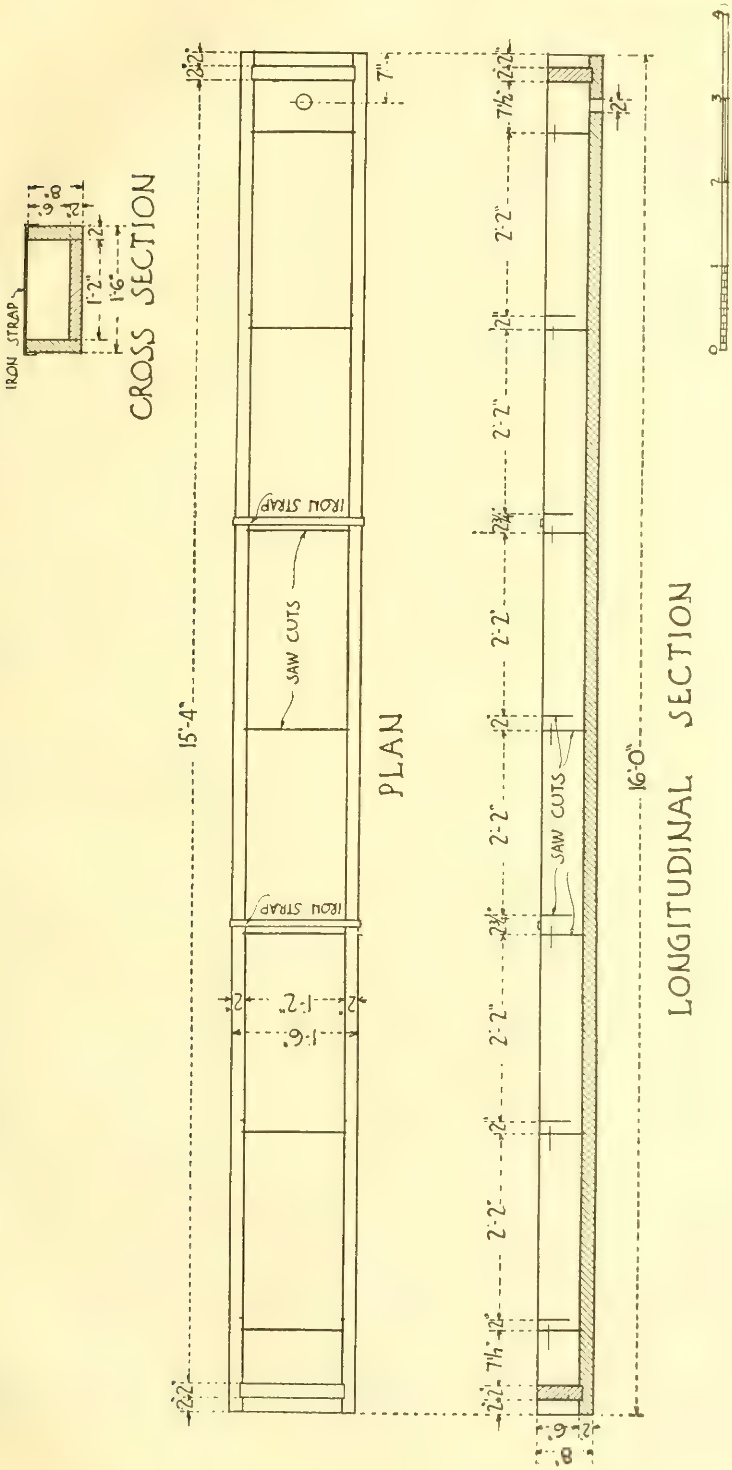


FIG. 6.—Plan of standard salmon-hatching trough.

the trough, with the exception of the space between the second and third and the fourth and fifth compartments. Here the dams are placed $2\frac{3}{4}$ inches apart for the accommodation of iron braces, which prevent the troughs from bulging. Only one dam is used at the foot of the trough. This reaches across and extends from the bottom to within $1\frac{1}{2}$ inches of the top. In the center of the space at the foot of the trough is a 2-inch outlet, provided with a hollow cedar or metal plug, placed at the proper height. The water is thus forced to flow under the upper dam upward through the basket of eggs, and thence over the lower dam, etc. The troughs are provided with canvas covers stretched upon light frames and made sunproof by saturation with asphaltum varnish, which is also thickly applied to the interior surface.

The egg receptacles are oblong-mesh wire-cloth baskets about $13\frac{1}{2}$ inches wide, 24 inches long, and from $5\frac{1}{2}$ to 6 inches deep, thus allowing them to project an inch or two above the surface of the water in the troughs. When wooden-rimmed baskets are used, the rim rests on the top of the trough and holds the basket 1 inch from the bottom. Arranged in this way the water passes under the riffle dam at the head of the compartment, beneath the basket, and then upward through the eggs. The metal rim, which has been adopted in recent years, is supported by metal lugs fastened to the edge of the basket, rests on the top of the trough, and holds the basket in the same position as the wooden rim. In both cases the basket, when in operation, should be kept flush against the lower riffle dam of the compartment in which it is placed, to force the ascent of the water through the eggs.

The number of eggs that can be incubated in a basket depends upon the species of salmon and the volume of the water supply. This varies with the chinook from 20,000 to 30,000; blueback, from 50,000 to 60,000; silver, from 30,000 to 35,000; humpback, from 40,000 to 50,000; and chum, from 33,000 to 38,000.

The eggs suffer no injury from being in numerous layers, as water is constantly forced through the mass, partially removing the pressure. The baskets are constructed of galvanized wire containing from four to six meshes per inch, three-fourths of an inch long, the size of the mesh varying with the size of the eggs to be handled. The oblong mesh permits the fry to pass through onto the bottom of the troughs when hatched, but it is not large enough for the passage of the eggs. The advantages of this apparatus are: (1) The top of the basket is above water, so that the eggs can not overrun or escape; (2) by tilting one end of the basket a little, or by lifting it and settling it back gently in place, the bad eggs are forced to the top and can be easily removed with the ordinary egg picker; (3) space is conserved, as the basket provides many times the number of eggs that could be accommodated on trays with an equal volume of water, the proper flow per trough being from 10 to 15 gallons per minute; (4) the ease and facility with which the mud can be discarded make it possible to remove all sediment collecting on the eggs by gently moving the basket up and down in the water several times.

The period of incubation of salmon eggs depends upon the water temperature. A very safe rule to follow is one originally formulated by Seth Green:

In a temperature of 50° F. the eggs will hatch in 50 days. Every additional degree of warmth lessens the incubation period by 5 days, and every degree lower than 50 prolongs it 5 days.

Salmon eggs are very hardy during the first few days, and while in this condition they are thoroughly gone over for the removal of the dead ones. At some stations it is customary after doing this to cover the eggs and leave them undisturbed until the spinal column is well formed, when the delicate stage has passed. This is not absolutely necessary, however, where skilled operators are employed. Men experienced in the work can handle the eggs throughout the entire period of incubation, and this is the most efficient method to pursue. When the number of unimpregnated eggs is great enough to warrant, they may be most advantageously removed by means of a salt solution, which should be applied only after the spinal column is well formed.

By means of this solution, which should consist of one part salt to nine parts of water, one is able to distinguish dead or unfertilized eggs at an early stage of development. The solution is held in a water-tight box or trough of 1-inch lumber, 40 inches long, 18 inches wide, and 12 inches deep. Inside of it is a second box of one-half inch lumber 3 inches less in width, 3 inches deeper, and provided with handles and a screen bottom. The dead eggs are removed with a net or scoop made of basket wire. The trough or outer box is filled to within a few inches of the top with water, and salt is added gradually and dissolved until the proper density is attained, this being determined by testing a few good and bad eggs in a small portion of the solution each time salt is added. This has been demonstrated to be a more satisfactory method than weighing or measuring, as salt readily absorbs moisture and varies in purity.

The box with the screen bottom is placed in the solution, wedged down, and a full basket of from 35,000 to 60,000 eggs poured into it. In less than one minute the good eggs will settle to the bottom, and the bad ones can be removed with the wire scoop. The inner box can then be lifted out and the good eggs returned to the basket and to fresh water, the whole process not requiring over three minutes. One solution can be used over and over again by adding sufficient salt to maintain a uniform density.

The box or trough was adopted because of convenience in handling and because it furnished the necessary amount of surface, a very important feature to consider, as the bad eggs, if crowded, would cause the good ones to float by mingling with them. Quite an extensive use of this method of cleaning the eggs has shown no deleterious results, and where there are over a thousand dead eggs in the basket at the time the empties are turned, the use of the solution will effect a saving of labor.

PACKING SALMON EGGS FOR SHIPMENT.

Cases made of 1-inch lumber and of suitable size for packing on horses or mules are used for moving eyed salmon eggs over rough mountain trails from the collecting fields. The bottom of the case is lined with a thick layer of moss and covered with a piece of mosquito netting. On this a layer of eggs is spread and covered with netting. Successive layers of moss, netting, and eggs are thus arranged up to the middle line of the case, where a firm wooden parti-

tion is fastened on. The packing is then resumed as before until the case is filled, when the cover is screwed on, and the eggs are ready to be transported.

For shipping eyed salmon eggs to various points in the United States what is known as the Atkins-Dinsmore case has been quite generally substituted for the old tray-shipment method described on page 84 of the Appendix to the Annual Report of the U. S. Commissioner of Fisheries for 1897. Eggs can be transported in the Atkins-Dinsmore case as soon as the eye spot is plainly visible and up to within a few weeks of hatching. When shipped at too late a period of development, however, the eggs will hatch en route and the embryos perish.

This method of packing eggs * * * has the special advantage of making a comparatively light package—a factor of great economic importance in transportation. The outside case may be an ordinary box of suitable dimensions.

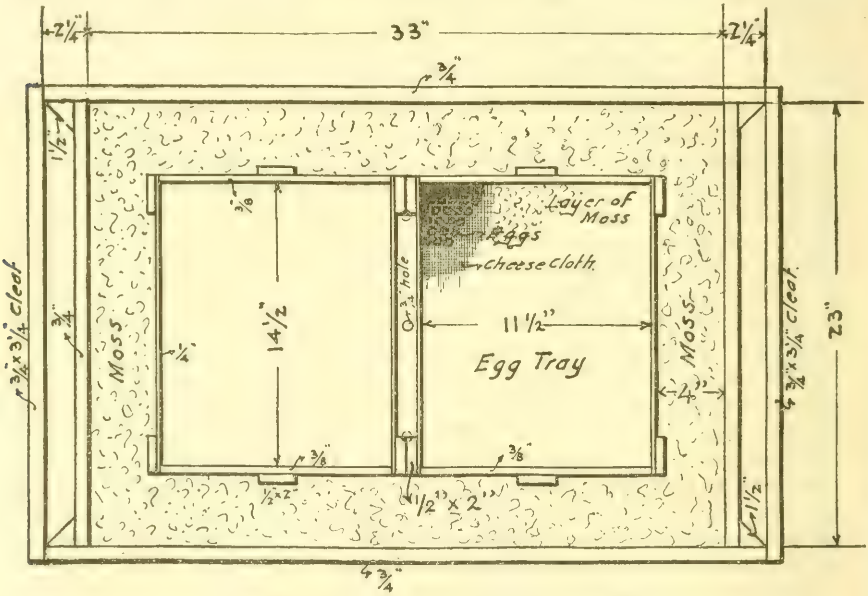


FIG. 7.—Atkins-Dinsmore shipping case. Plan.

In it are packed, surrounded by moss, several boxes made of three-eighths-inch boards, and usually 12 inches wide by 15 inches long by 3½ inches deep, each box containing a mass of 10,000 to 20,000 eggs in mosquito netting, with moss around all sides. No ice is used, care being taken that the packing be done in a temperature below 50°, that all packing material be kept in a place slightly below freezing point, and that the moss in which the eggs are packed be sprinkled with snow. This method of packing is an economical one for shipments of eggs of Salmonidæ during cold weather, but can not advantageously be used for eggs of spring-spawning fishes unless there is available a cold-storage room in which to do the packing. Recently the superintendent of the Baker Lake (Wash.) station, who has had occasion to ship eggs of steelhead trout and Pacific salmon in warm weather, has packed them in light cases with alternate layers of moss, and then placed two tiers of these thin cases side by side in an outer case with a large hopper of ice over the whole, the drip passing down between the two tiers of inner cases. The chief advantage of this case for long-distance shipments is in the fact that less ice is required than in other forms of cases using ice, with a consequent saving in transportation charges. It can also be used in warm as well as cold weather.[a]

[a] Titcomb, John W. Loc. cit., pp. 743.

While the methods described above have been successfully employed in the transportation of eggs across the United States and

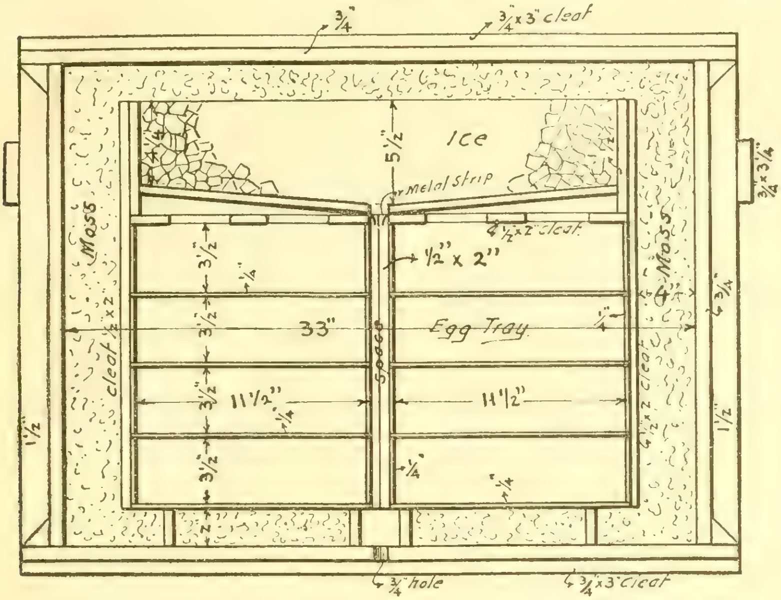


FIG. 8.—Atkins-Dinsmore shipping case. Longitudinal section.

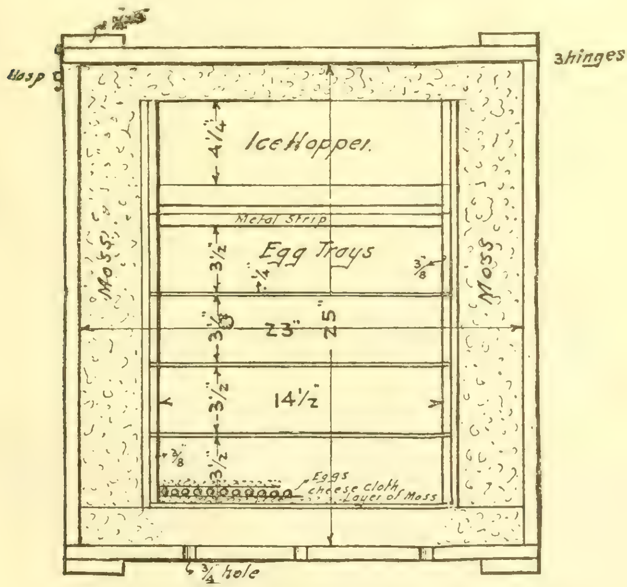


FIG. 9.—Atkins-Dinsmore shipping case. Cross section.

also to Europe without an attendant, shipments of eggs to points south of the Equator, usually leaving this country in winter and arriving at their destination in summer, have called for more than

usual attention to the methods of packing them, and a caretaker is quite essential.

The Argentine shipping case, successfully used under such conditions, has been described by John W. Titcomb as follows:[a]

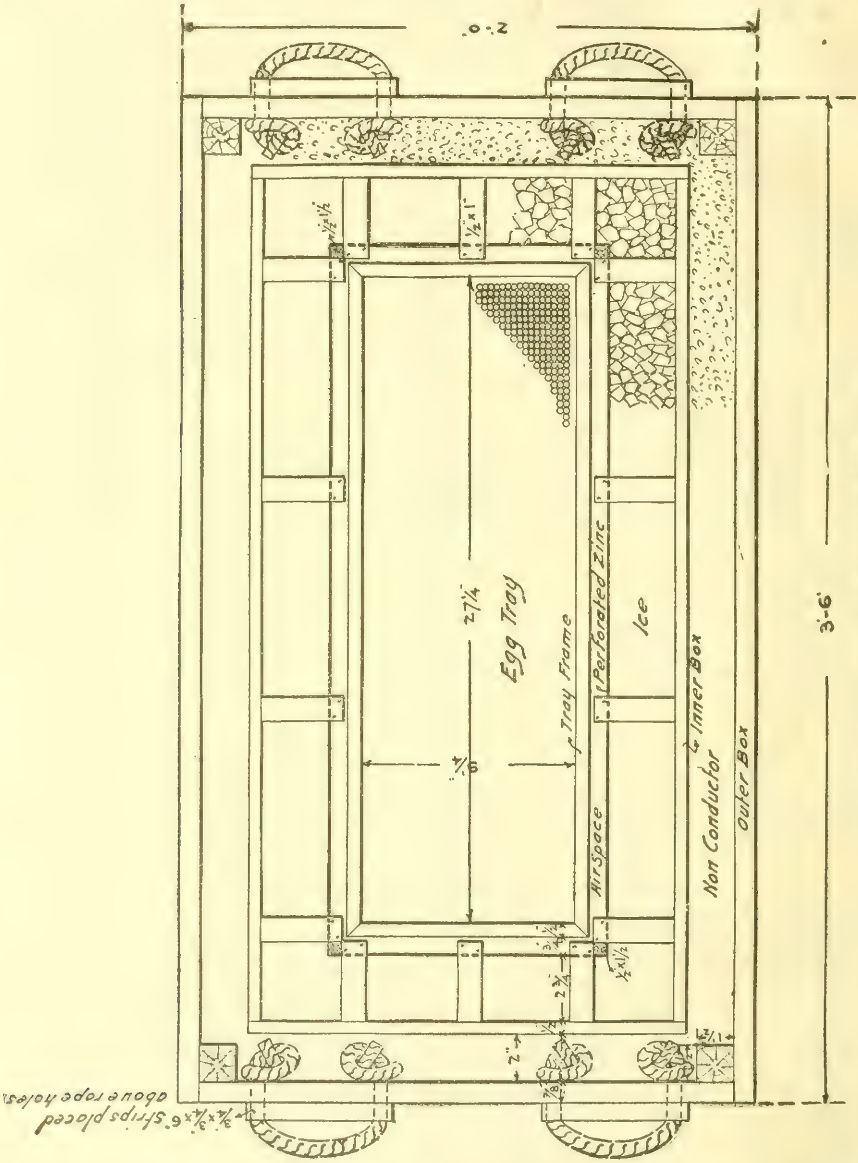


FIG. 10.—Argentine shipping case. Plan.

A highly efficient form of shipping case has been developed during the past few years for the transportation of eggs of the Salmonidæ from this country to Argentina. This case is 3 feet 6 inches long, 2 feet wide, and not exceeding 30 inches high, outside measurement, and is constructed of selected tongued and grooved lumber. It has double walls, with bottom and top common to

[a] Titcomb, John W. Loc. cit., pp. 747-749.

both, the 2-inch space between the walls being filled with nonconducting material, preferably tightly packed shavings. Between the inner wall and the stack of trays is a $2\frac{3}{4}$-inch space for ice, separated from the trays by perforated zinc. Between the latter and the trays, in a three-fourths-inch space, are the vertical supports of the zinc, viz, double corner supports, one being one-half by $1\frac{1}{2}$ inches, the other being one-half by 1 inch; two intermediate supports of one-half by 1 inch material, which are provided on either side of the case and one at each end; and cross braces of one-half by 1 inch material, which extend from the uprights to the inner walls of the case.

The ice hopper, 3 inches in depth, and having the same outside dimensions as the trays, rests upon the latter and fills the space between the uppermost tray and the top of the case. It has a perforated zinc bottom, and, to facilitate handling, cleats of small ropes are attached to it. The top of the case is insulated with a 2-inch thickness of nonconductor covered with sheet zinc, this insulation fitting closely into the chest when closed, and thus covering not only the ice hopper, but the ice spaces around the sides as well. In the bottom grooves lead to a three-fourths-inch drain hole, which is provided with a

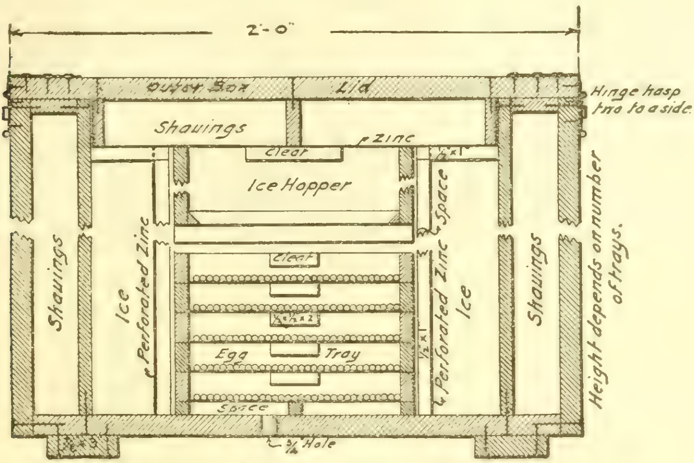


FIG. 11.—Argentine shipping case. Section.

cork. Two cleats seven-eighths by 3 inches are attached lengthwise to the bottom on the outside.

The trays are one-half inch deep, 27 inches long, and 9 inches wide, inside measurement, the frames being of one-half by one-fourth inch material. The bottom of each tray is covered with wire cloth, No. 25 gauge, about 12 meshes to the inch, stretched tightly to prevent sagging and consequent uneven distribution of the drip water. A narrow binding of cloth is tacked around the bottom of each tray to prevent the wire edge from catching on the mosquito-net covering of the tray beneath. On the inside ends of the trays are fastened short lifting cleats, and wedges hold the trays securely in place. The bottom tray rests on three one-half-inch cleats extending lengthwise of the case, one at either side and the other in the middle. It is important to have the trays of uniform size that they may be interchangeable.

The trays and interior of the case are coated with asphaltum. To facilitate opening from either side, four hasps are used, two on each side of the case. Two rope handles side by side are placed on each end of the case, with a cleat of three-fourths-inch material just above the holes for each handle.

Eggs selected for shipping should barely show the eyespots without the aid of a glass. In packing, a layer of damp moss is spread one-fourth of an inch deep as evenly as possible over the tray bottom, and upon this is placed a covering of mosquito net or bobbinet. The eggs are laid upon the netting one or two layers deep, spread to within one-half inch of the tray frame, and covered with another piece of netting to keep them separate from the moss, which is sprinkled in a light layer over it, filling the tray. The netting is cut large enough to extend over the outer edges of the tray, so that the eggs may not be disturbed when a tray is lifted for examination.

On shipboard, as the greater part of the journey is made, the cases of eggs are kept in one of the fruit or cold-storage rooms having a temperature of about 38° F. To this room the attendant has access, and it is his duty daily to moisten the eggs by pouring through the ice hopper water of the same temperature as the eggs, 34° to 35°. The ice compartments are frequently replenished, and the eggs are picked over whenever necessary.

It will be seen that the method of caring for the eggs is not novel. The chief improvements in the case are to make it easy for the caretaker to handle the eggs in the crowded quarters of a ship's storage compartments and to facilitate handling each individual tray.

WATER SUPPLY FOR HATCHERY.

One of the most important factors to be considered in connection with salmon propagation is the water supply, which should always be taken from a stream that salmon are known to frequent for spawning. Spring water or water from a spring-fed creek is objectionable, as it shortens the incubation period, bringing out the fry at an earlier period than if hatched under natural conditions and at a season of the year when the natural food supply in the streams is at its lowest ebb.

In choosing a site for a salmon hatchery the matter of conveying water thereto at a proper height for a gravity service should be planned for, if possible. The supply may be conducted through a substantially built flume or by a pipe line, the dimensions of either to be governed by the extent of the work contemplated, having in mind the further development of the plant and the size of the pond system it is desired to establish. The point for the intake should be selected with the view to its protection, so far as is possible, from the ravages of floods and ice. This may be accomplished by means of piling or sheer booms. In some cases the construction of a low dam will be required in order to raise the water to the proper level to enter the flume or pipe line.

Water taken from an open stream always contains more or less sediment, necessitating the use of a filter for the elimination of the greater part of it. A small quantity of sediment in the water supply is not objectionable; in fact, it is apparently beneficial.

Where a proper fall can be secured, with a sufficiently rapid current at the point of intake, the water can be delivered by means of a current wheel, provided climatic conditions are favorable to its operation. A wheel for this purpose should be constructed on the order of a large undershot water wheel, with buckets on the outside of the rim. As the wheel revolves the buckets fill and empty into a trough or tank connecting with the supply flume leading to the hatchery.

CARE OF THE FRY.

The eggs of the chinook salmon, as do those of the other Salmonidæ, hatch very gradually at first, only a small percentage coming out the first day. But the number increases daily until the climax is reached, when large numbers of young burst their shells in a single day. Great care and vigilance are required at this time. The vast numbers of shells rapidly clog up the guard screens at the outlets of the troughs, which should be kept as free as possible by thorough cleansing from time to time.

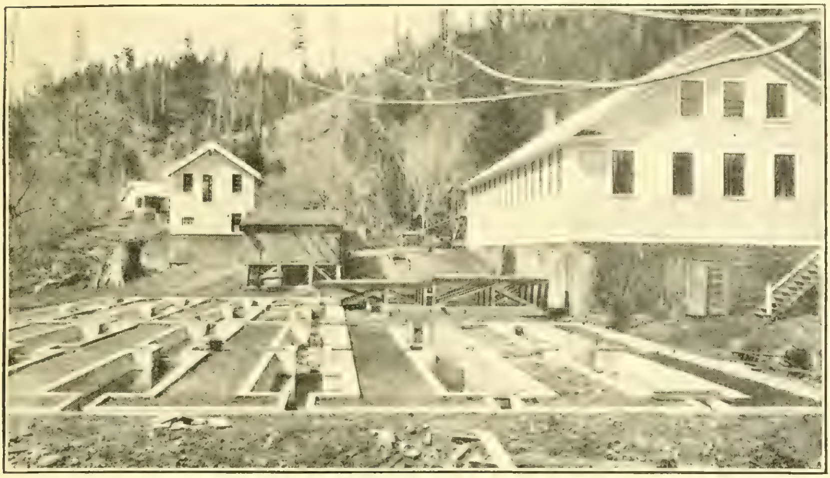


FIG. 1.—HATCHERY AND FEEDING PONDS, DUCKABUSH (WASH.) STATION.

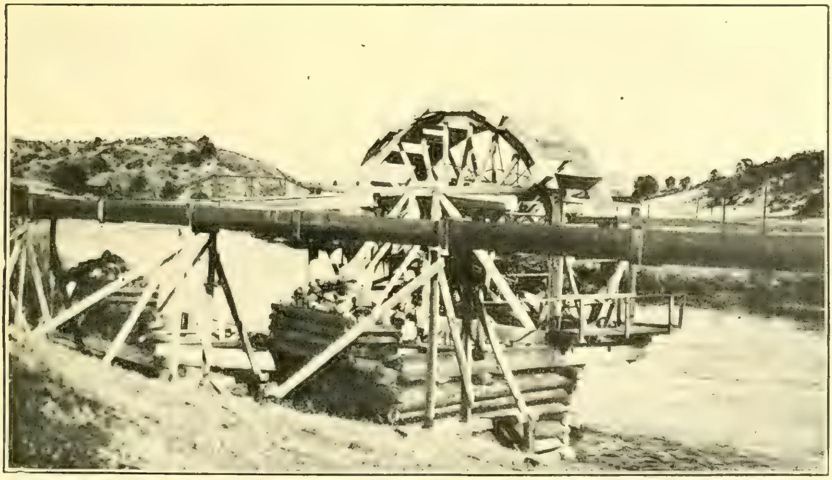


FIG. 2.—CURRENT WHEEL, HORNBROOK STATION, KLAMATH RIVER. CALIF.

After all the eggs are hatched and the baskets and riffle dams are removed from the troughs, each trough is divided into three equal compartments for holding a certain proportion of fry by inserting in the saw scarfs which carry the riffle dams 7 by $14\frac{3}{8}$ inch screens, made of No. 9 gauge zinc. The size of the perforations, which are horizontal in shape, should be governed by the species handled, and the four outer edges of each screen should have a one-half inch margin of unperforated metal. The number of fry that can be held until the absorption of the yolk sacs ranges from 30,000 to 50,000 per trough, varying with the species and the water supply available.

In the deep trays the newly-hatched fish are mixed with unhatched eggs, and the advantage of the oblong mesh in the bottom of the trays becomes apparent. This mesh is too narrow to allow the eggs to fall through, but the hatched fish, being comparatively long and narrow, easily slip through the long meshes into the space below. They should be assisted by gently raising and lowering the tray at intervals, taking care not to raise them out of the water, as at this tender age a slight pressure against the wire of the tray will often produce fatal injuries. On this account too much caution can not be exercised in regard to handling them out of water during the first stages of the yolk-sac period, for the injuries can not be seen at first, and often the death of the fry is the first warning that they have been injured.

After the eggs are all hatched and the young fish are safely out of the trays and on the bottom of the troughs, their dangers are few, and they require comparatively little care. Almost the only thing to be guarded against at this period is suffocation. Even where there is an abundance of water and room, with a good circulation, they often crowd together in heaps, or dig down under one another until some of them die from want of running water, which is not an inch away from them. The best remedy in such a case is to thin them out.

FEEDING THE FRY.

In recent years it has become well recognized that real success in the propagation of the Pacific salmons is determined in large measure by the extent to which the young are reared to the fingerling stage before liberating. The former practice of planting defenseless fry in wholesale numbers a short time before the final absorption of the yolk sac is now almost obsolete. This pertains particularly to the blueback and silver salmons and in less degree to the chinook, for these are known to pass a part or the whole of their first year's existence in fresh water, a period of residence that has been determined conclusively, chiefly as the result of general investigations and study of salmon scales conducted in recent years by Dr. C. H. Gilbert, of Stanford University, Calif.

The demand for fingerlings which has naturally followed this recognition of the great value of fingerlings over fry has developed the necessity for a cheap food, one that will furnish proper nourishment for the young fish and be available in large quantities, as the cost of liver, which has long been a favorite article of food for young fish on the west coast, has become prohibitive, except for occasional use and to afford a change of diet for a short period.

One of the first cheap foods to be utilized in large quantities by the Bureau of Fisheries was the Columbia River smelt, which was first tried at the Oregon stations about five years ago. These fish can be purchased during the run at the height of the season for $20 per ton at a cold-storage plant in Portland, Oreg. An additional charge of $20 per ton covers sharp freezing and storing for a period of six months, and this, together with transportation charges, makes the average cost of the fish about 2½ cents a pound delivered.

Smelt have been fed both raw and cooked. When used in the raw state the fins and heads are removed, and the fish are ground once through the coarse plate of an Enterprise meat chopper, after which they are run through the fine plate twice. However, this method has not proved very satisfactory, as smelt are very oily, and, in feeding, difficulty has been experienced in keeping the troughs clean. Intestinal trouble is also feared from the innumerable small, sharp bones.

The method which has given most satisfactory results is to place the smelt in 50 or 100 pound lots in a farm kettle and cook them until the bones become softened. After this a quantity of the cooked mass convenient for handling is placed in gunny sacks and permitted to drain thoroughly. The mass in the sack is then transferred to a press of convenient size, operated by an ordinary house jack, and is pressed into cakes 12 inches square and varying from 3½ to 4 inches in thickness. The burlap forming the sack is peeled away and is serviceable for further use. Quantities of this food can be prepared at one time, and, if kept in a cool, dry place, will remain in a wholesome condition for several days. When needed for food it is grated by means of a homemade power grater and screen, the degree of fineness depending upon the age of the fish to be fed. After this operation it presents the appearance of coarse meal. It can be scattered over the surface of the water and is cleaned up by the fish before it reaches the bottom. Prepared in this manner it makes a good, clean, rich food, and the fish take it readily. Its cost is also very moderate.

Beef and hog melts have been successfully used in conjunction with mush, both for the purpose of varying the diet, and with the view of eliminating the use of liver in large amounts after the fish are a few weeks old. The cost of this material will average about 3 cents per pound.

Culled canned salmon, or "do overs," have also been employed to good advantage in the feeding of young salmon. The contents of the cans are first thoroughly heated and then pressed and grated in the manner described above in the preparation of smelt. Particular attention is invited to this method of using canned salmon as fish food in view of the fact that considerable complaint has been made as to the results of its use in the past. If prepared in the manner specified, the material is certain to give satisfactory results.

After several years' success in the feeding of canned salmon it occurred to representatives of the Bureau that the fish used in a spawning operation, if properly preserved and prepared, would make a good and inexpensive food. Instructions were accordingly issued to all the west coast superintendents, including those in Alaska, to put up a quantity of the spawned salmon, and it is extensively used at those stations at the present time. After being relieved of their eggs the fish are skinned, split, and carefully boned.

They are then placed in tanks or barrels, with alternate layers of salt, water being added in sufficient amount to keep the brine well over the top layer.

The material has also been prepared by dry salting in dairy salt and packing it in a dry, tight box or other container, weighing it down in a solid mass. The fish are then taken out, rinsed in fresh water, and hung over a pole in the dry house. A slow heat is applied at first to toughen the fiber, following which they are kept in the dry house until quite hard and dry, when they are packed in boxes between layers of papers to absorb any moisture and held in a dry storage until needed.

Still another method was tried at the Bureau's California stations, where a quantity of sundried or sun-cured salmon was prepared without salt, the climatic conditions being favorable for curing salmon in that manner until late in the fall.

Several methods of preparing this food were adopted. In all cases, however, the fish were first soaked well, preferably overnight, in running water, to remove the salt. Some were then cooked, pressed, and grated; others were prepared by grinding in an Enterprise meat chopper and mixing the meat with a mush made from middlings. Quantities have also been prepared and fed in the raw state. In all forms the material has proved excellent, and when used in conjunction with small quantities of liver or plucks, to vary the diet, the results have been eminently satisfactory. Its cost, based on the lots which have so far been put up, has averaged 1 cent a pound. When prepared in large quantities, it should be materially cheaper.

Most excellent results were attained with this food at one of the Puget Sound stations of the Bureau of Fisheries. In a slough where several hundred thousand fish had been placed at the time of the absorption of the yolk sac, sides of salted salmon were laid on the bottom. As the meat softened, hundreds of young fish could be seen working on it, and it was finally all devoured. The fish remained in the slough under the care and observation of an attendant, attained a rapid growth, and developed into splendid fingerlings.

Under such an arrangement the expense of salmon rearing is reduced to a minimum, and work of similar character should be encouraged on all salmon streams where the natural conditions are favorable.

In connection with rearing operations the importance of providing a mixed diet can not be too strongly emphasized. If the principal food consists of the prepared fish, a food of liver and mush should be given frequently. Where this is done as often as once a day, it will be found to produce the most rapid growth. No matter how good any one food may be, nor how cheaply it is prepared, the best possible results will be attained where a variety is used.

PLANTING YOUNG SALMON.

When the salmon have reached the proper age for distribution, they should be released on or near the natural spawning grounds, in the most protected spot that can be found. It is unwise to liberate young salmon before they have absorbed the yolk sac, and where the

necessary facilities exist it is advisable to feed them until they have attained a length of at least 2½ inches, as fish of that size are much more likely than fry to elude their enemies.

The following information bearing upon the ages at which salmon should be planted is taken from a report of Dr. C. H. Gilbert, Professor of Zoology, Stanford University, on investigations made by him for the U. S. Bureau of Fisheries and for the commissioner of fisheries of British Columbia:

The blueback spawns normally either in its fourth or fifth year, the chinook salmon in its fourth, fifth, sixth, or seventh year, the females of both species being preponderatingly four-year fish.[a]

The young of both blueback and chinook salmon may migrate seaward shortly after hatching, or may reside in fresh water until their second spring. Those of the first type grow more rapidly than the second, but are subject to greater dangers and develop proportionately fewer adults.[a]

[In the case of the blueback salmon] examination of scales from all the important blueback streams of the Province has shown for each basin that adult fish are derived from yearling migrants, to the practical exclusion of those which migrate as fry. Out of some 8,000 bluebacks of the 1913 run, only 12 fish seemed with some probability to have developed from fry migrants. It would seem, then, that with few exceptions the fry of this species perish after entering the sea. The only alternative to this conclusion is that fry develop in the sea in precisely the same manner, at the same rate, and with all the local peculiarities marking those of their own basin, which develop for a year in their native lake. To one acquainted with all the facts, such an hypothesis appears impossible and absurd.[b]

The deplorable waste occasioned by the loss of vast numbers of fry can not be checked, it would seem, in the case of such progeny as are the result of natural spawning. They can not be held back from migrating as fry if the instinct seizes them. But the case is different in hatchery practice. Here [British Columbia] it is still the custom to release the young as soon as the egg sac is absorbed and free feeding begins. But, in view of the conditions here pointed out, it would appear to be imperative that the fry of the year hereafter should be held in troughs or ponds and fed until midsummer, when the time for downward migration will have passed. They can then be deposited in the lake, with full confidence that they will pass to sea as yearlings the following spring.[b]

Silver salmon spawn normally only in their third year. The young migrate either as fry or yearlings, but adults are developed almost exclusively from those which migrate as yearlings.[a]

Chum salmon mature normally either in their third, fourth, or fifth year; humpback salmon always in their second year. The young of both species pass to sea as soon as they are free swimming.[a]

The term " grilse " as used for Pacific salmon signifies conspicuously undersized fish which sparingly accompany the spawning run. They are precociously developed in advance of the normal spawning period of the species. So far as known, the grilse of the chinook, silver, and chum salmons are exclusively males, of the blueback, almost exclusively males, except on the Columbia River, where both sexes are about equally represented. The larger grilse meet or overlap in size the smaller of those individuals which mature one year later at the normal period.[a]

The great differences in size among individuals of a species observed in the spawning run are closely correlated with age, the younger fish averaging constantly smaller than those 1 year older, though the curves of the two may overlap.[a]

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[a] Gilbert, C. H.: Age at maturity of the Pacific coast salmon of the genus Oncorhynchus. Bulletin, U. S. Bureau of Fisheries, Vol. XXXII, for 1912, pp. 21–22. Washington, 1913.

[b] Gilbert, C. H.: Summary of Contributions to the life-history of the sockeye salmon. (No. 1.) British Columbia. Report, Commissioner of Fisheries, for 1913. pp. R10–R11. Victoria, 1914.